

**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

Soil Gas As A Monitoring Tool Of Deep Geological Storage Of Carbon Dioxide: Results From The ENCANA EOR Project In Weyburn, Saskatchewan (Canada).

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Weyburn soil-gas surveys: Summer 2001 data



BGS – British Geological Survey

Mick Strutt, D. Jones.

BRGM - Bureau de recherches géologiques et minières

J.C. Baubron, M. Brach.



INGV – Istituto nazionale di geofisica e vulcanologia

F. Quattrocchi, N. Voltattorni; G. Granieri; C. Cardellini; G. Chiodini.

USR - Università “La Sapienza” di Roma

S. Lombardi, S. Beaubien.



JD Mollard and Associates Limited, Regina, Canada.

L. Penner



Overall Objectives:

➤ Soil gas and related studies to:

- Establish baseline soil gas values using grid sampling and profile over anomalies
- Evaluate natural variations in soil gas including seasonal effects
- Compare baseline data with future datasets
- Identify sites of higher gas flux that may be indicative of deep gas escape
- Enable long term monitoring to evaluate possible escape of injected CO₂



Partners Contributions:

➤ Collection and analysis of soil gas samples:

- BGS: CO₂, O₂, CH₄, radon and thoron *in situ*.
- BRGM: Helium by field analysis and long term radon data procurement for possible migration pathways.
- INGV: Field CO₂ flux measurements.
- URS: CO₂, O₂, N₂, light hydrocarbons and sulphur species by field portable gas chromatography and more sensitive laboratory GC. Laboratory analysis for helium.



Fieldwork methods

➤ July 2001:

- Collection of soil gases and analysis by field portable GC.
- CO₂ flux measurements over grid area.

➤ September 2001 and 2002:

- Soil gas radon, thoron, CO₂, O₂, CH₄ and barometric pressure
 - Complete 320 site baseline grid (250m spacing)
 - Detailed profiles over anomalies (25m spacing)
 - Daily background site measurements
- Detailed traverses using gamma spectrometry (2001 only)
 - Investigate relationship to radon and provide background geological information
- Helium tracer MS measurements for possible gas escape pathways
- Depth profile assessment (2002 only)

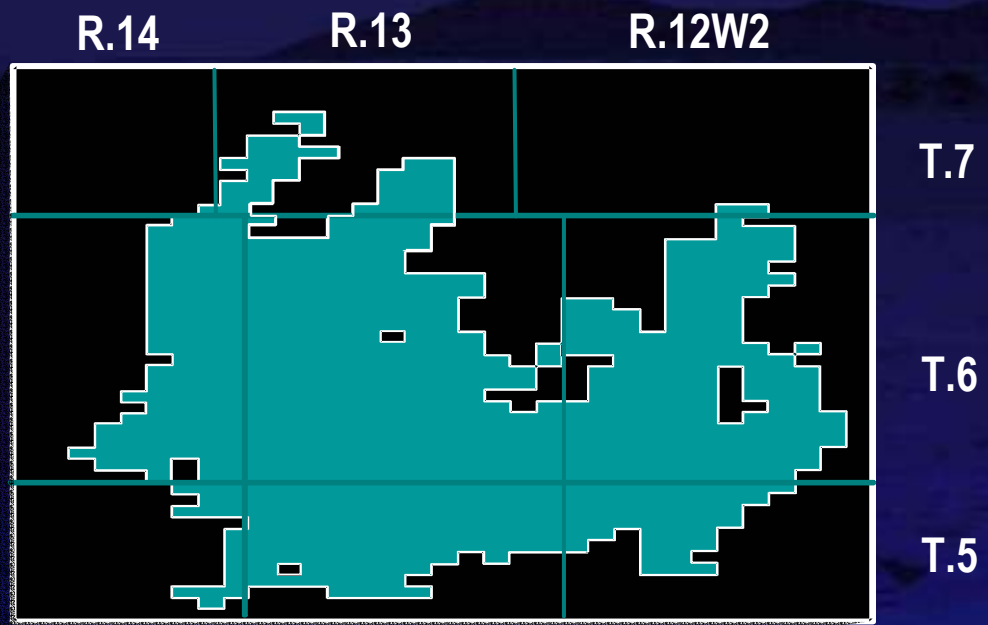


Approach: Radon and CO₂

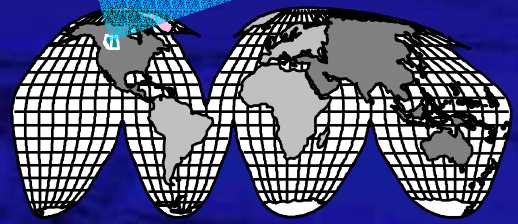
- Compare annual gas data from different instruments/methods with University of Rome/INGV for carbon dioxide and radon
- Direct comparison with University of Rome data to allow merging of data and examination of seasonal variation
- Examine soil gas anomalies to help identify possible sites of natural deep gas escape (for installation of long term radon monitors by BRGM)
- Compare results with lineament analysis, known structures etc.



Weyburn Unit



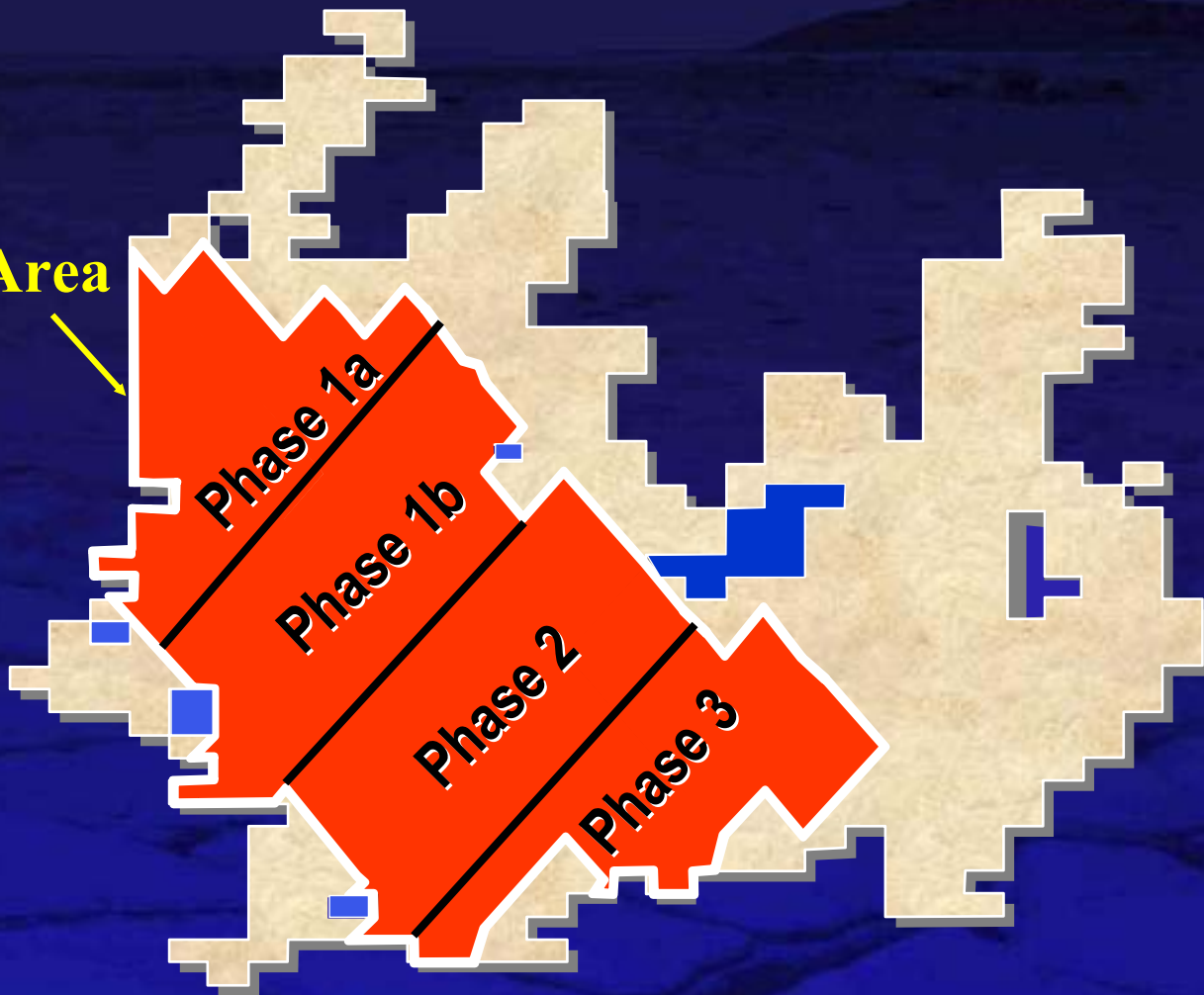
Discovered in 1954 the Weyburn Unit covers an area of 70 sq. mi





Rollout of the flood

EOR Area

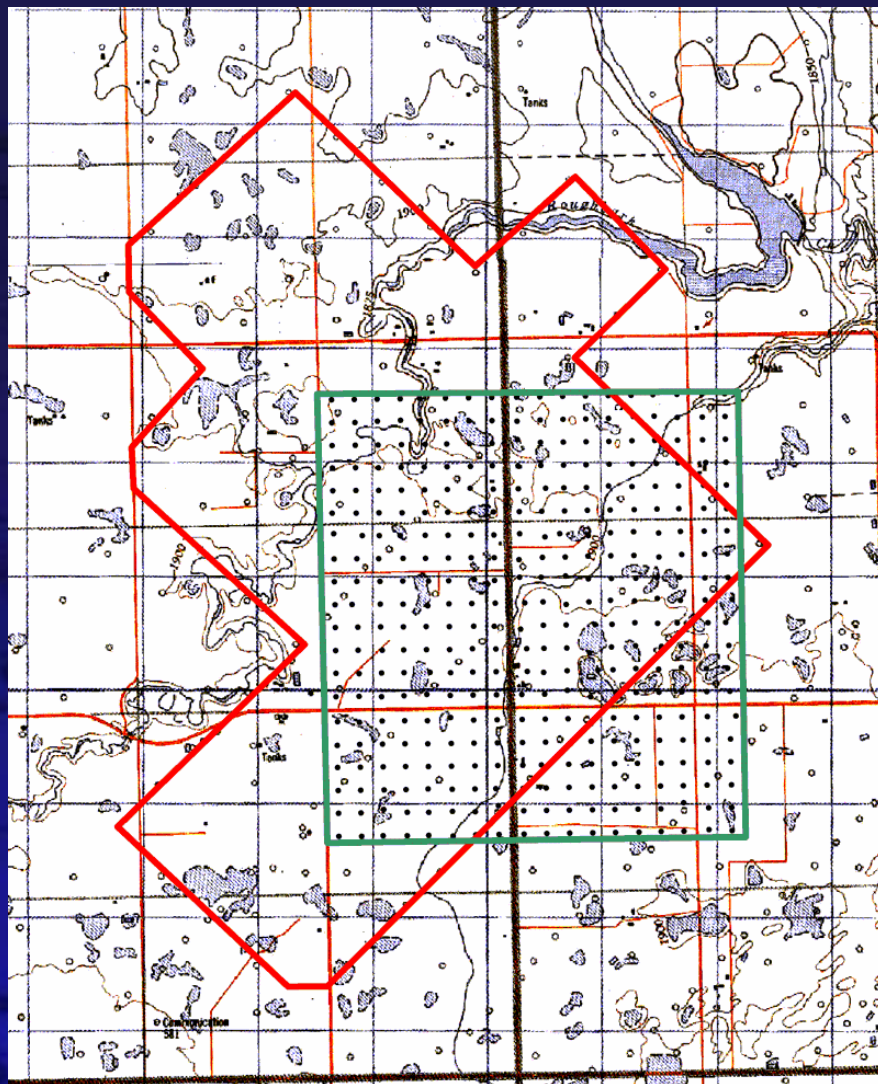


T.7

T.6



Gas Sampling Area



Injection area 1A ———

2001 grid gas
sampling sites ———

September 2001

Hot & Dry



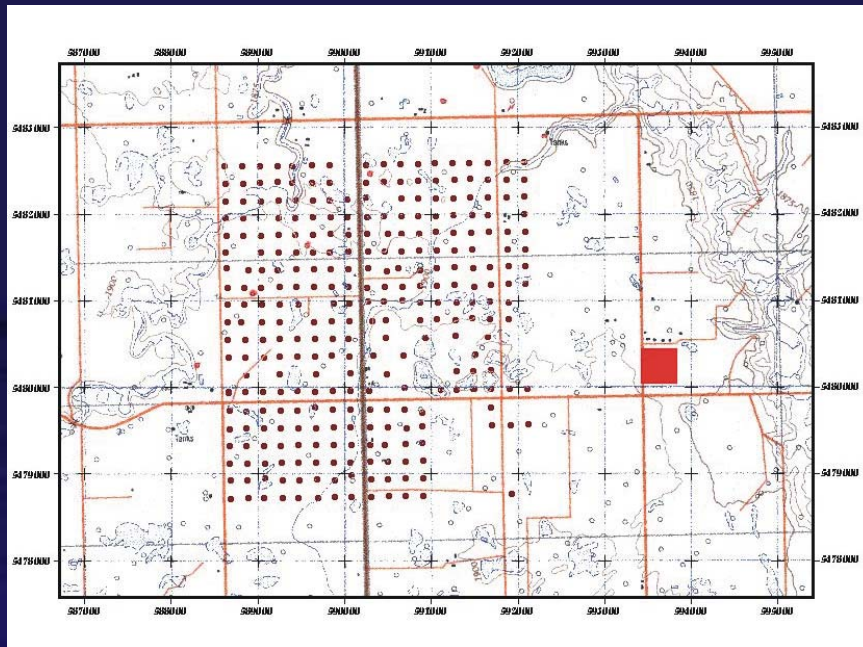
September 2002

Cool & Wetter

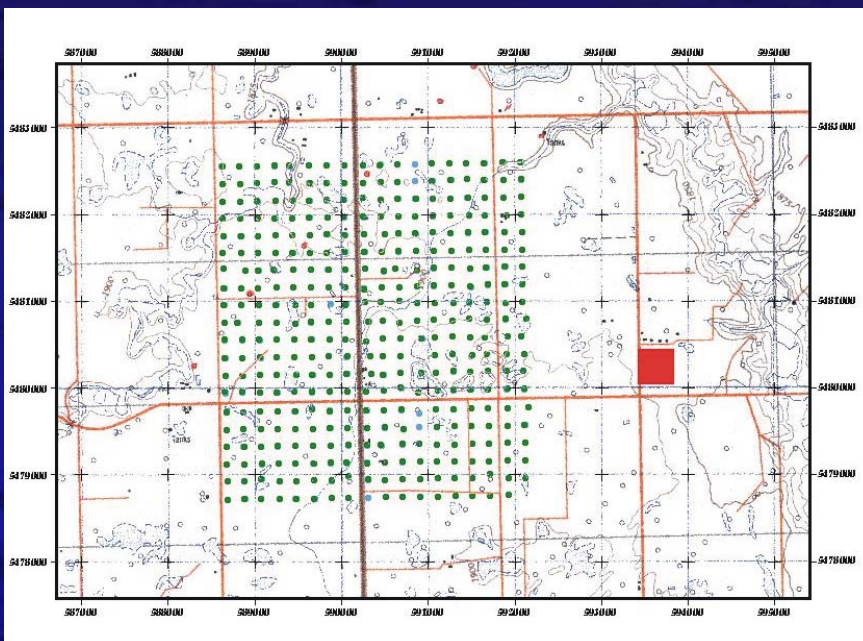








September 2001:
Grid sites sampled



September 2002:
Grid sites sampled



2001 Soil Gas Sites

BGS



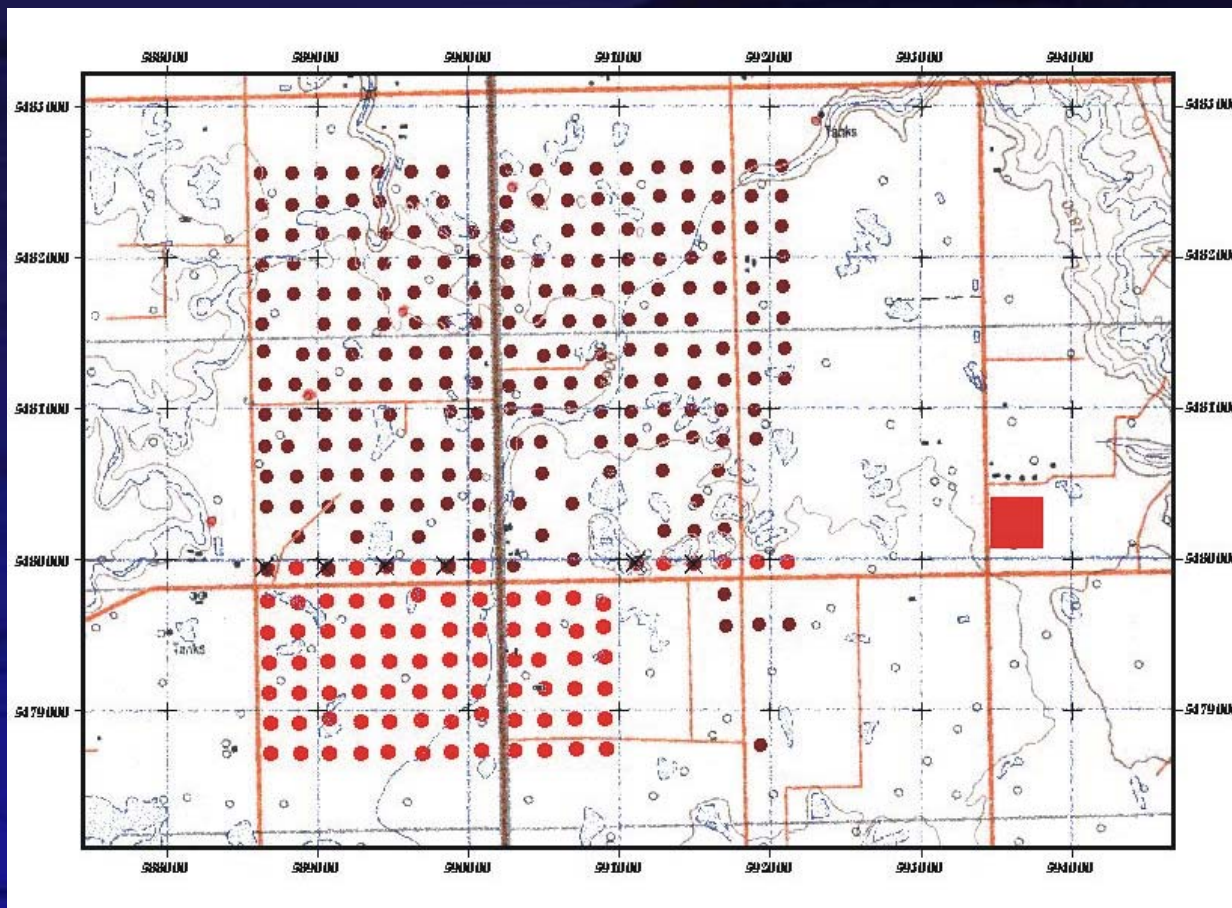
Rome



BGS &
Rome



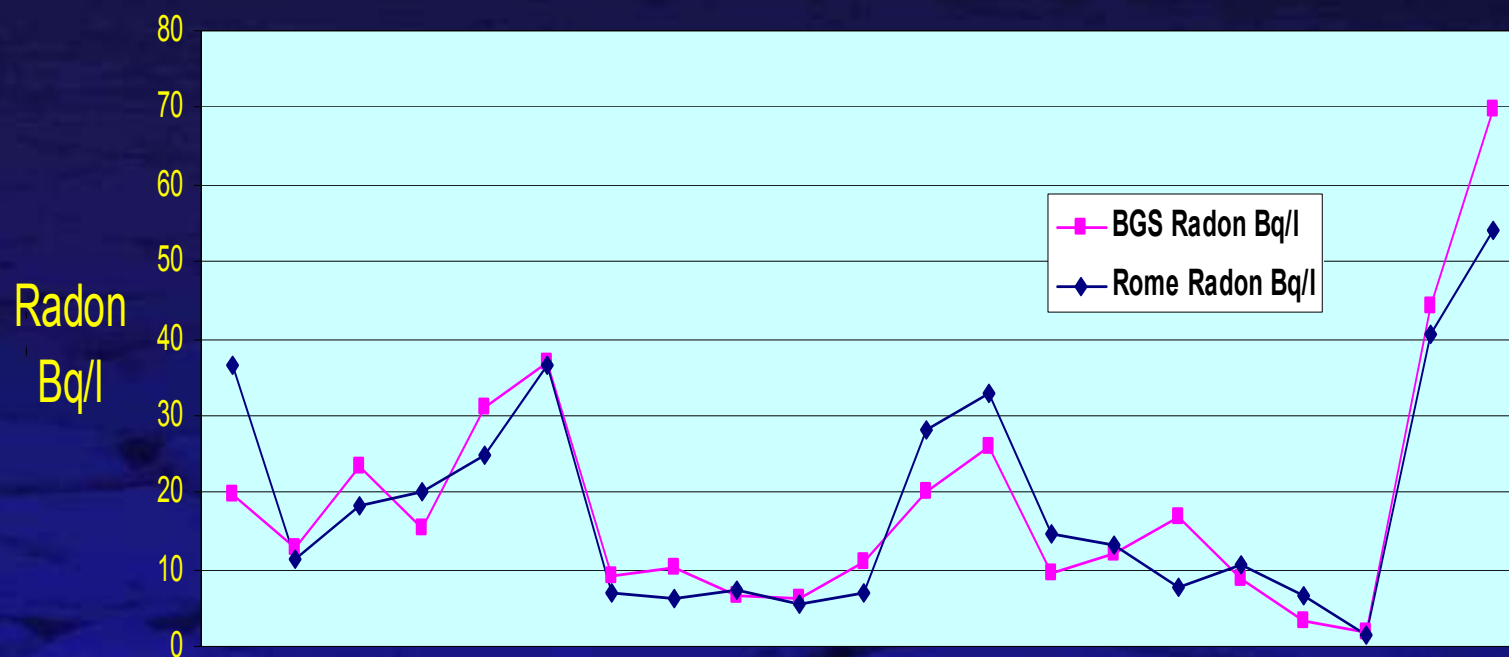
Control Site

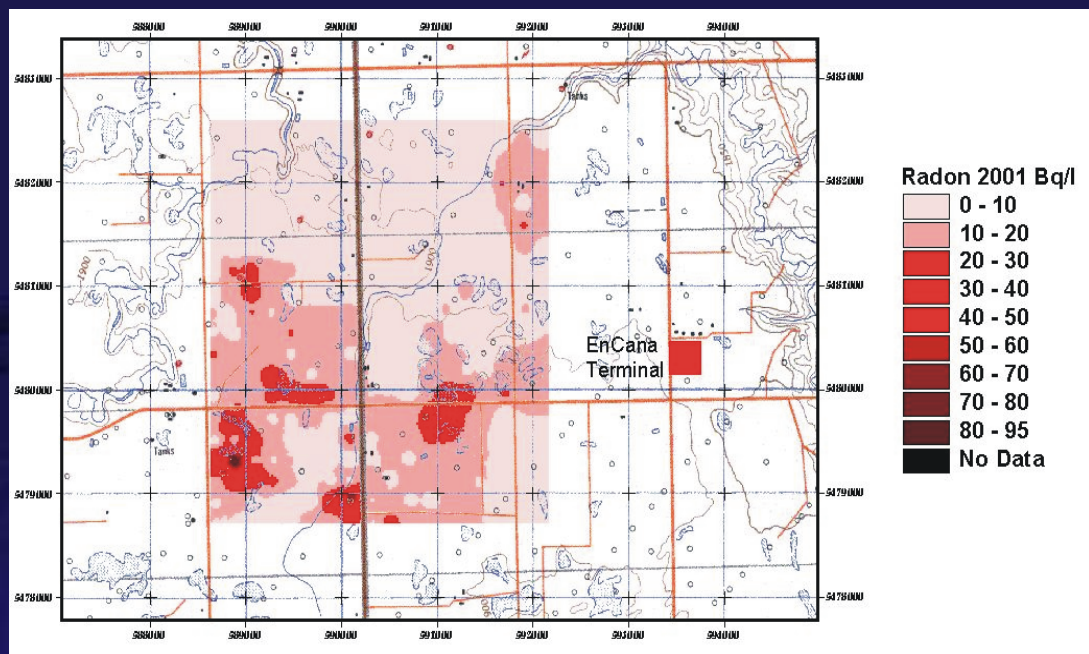




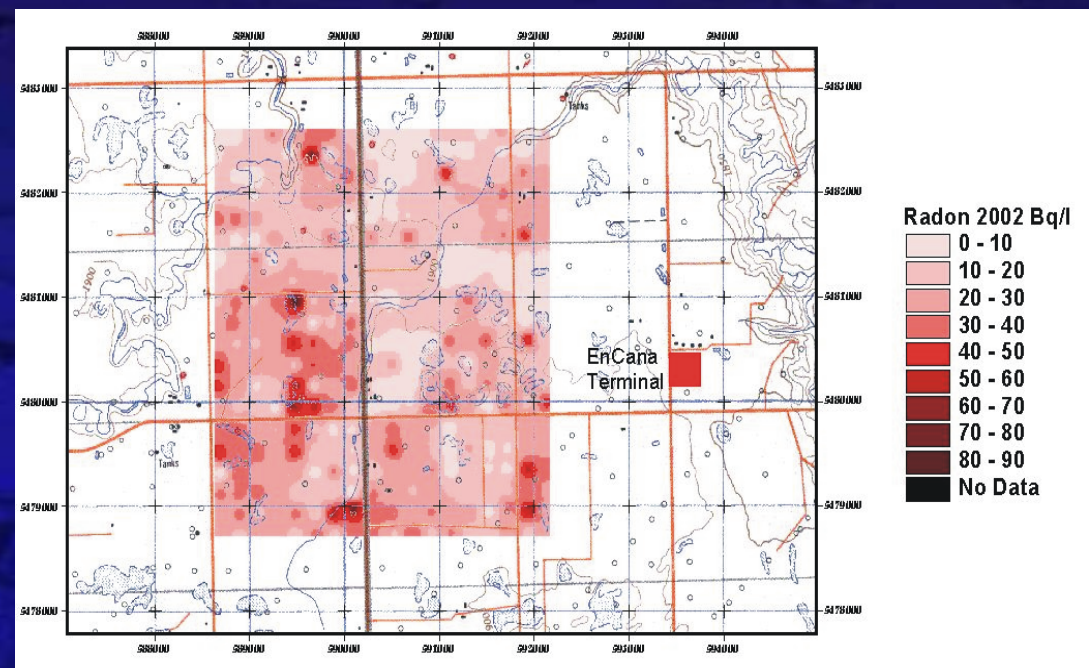
Calibrated radon data

Calibrated Rome & BGS Radon Bq/L

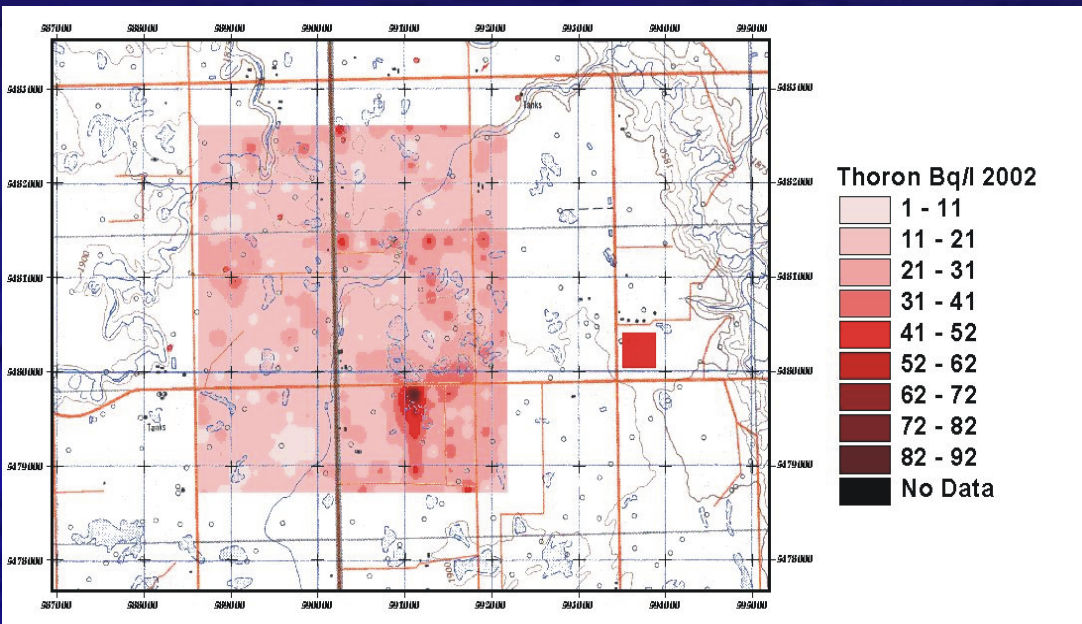
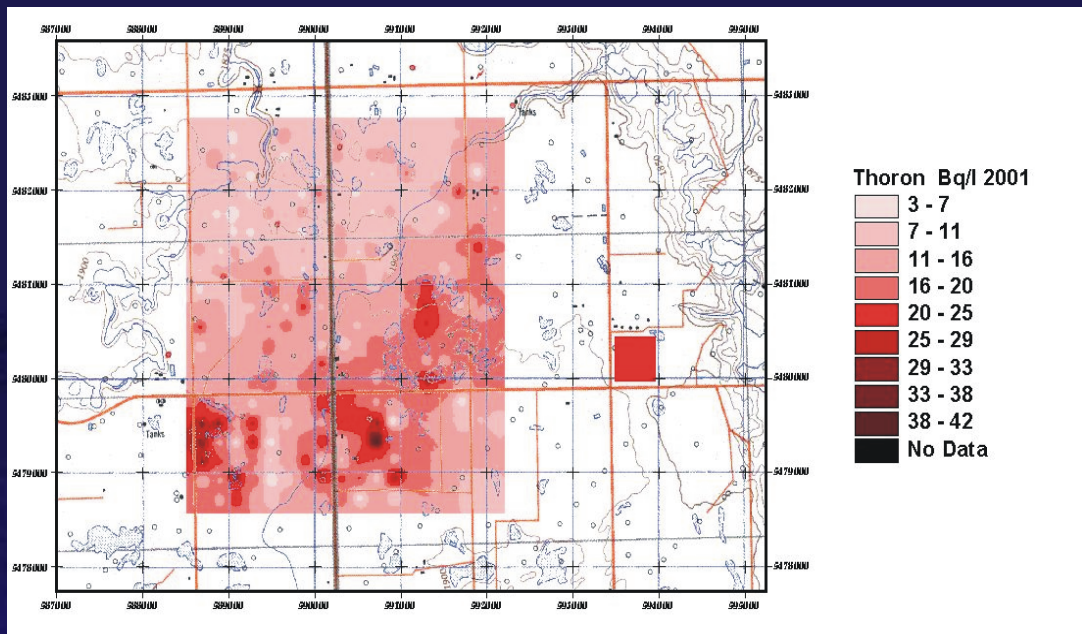




Comparison of Radon (Bq/l) between 2001 and 2002



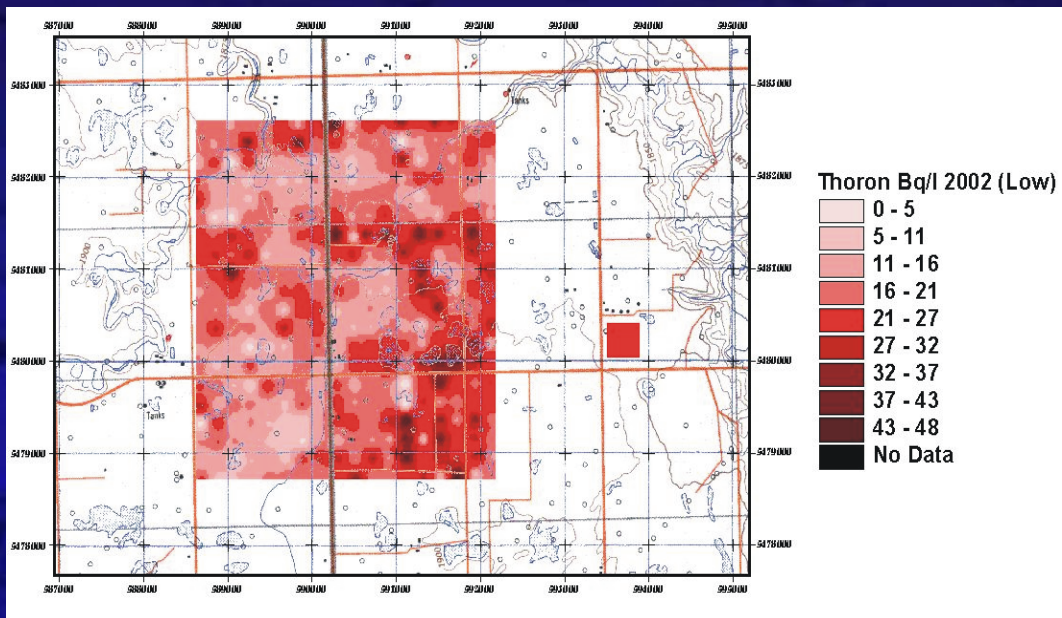
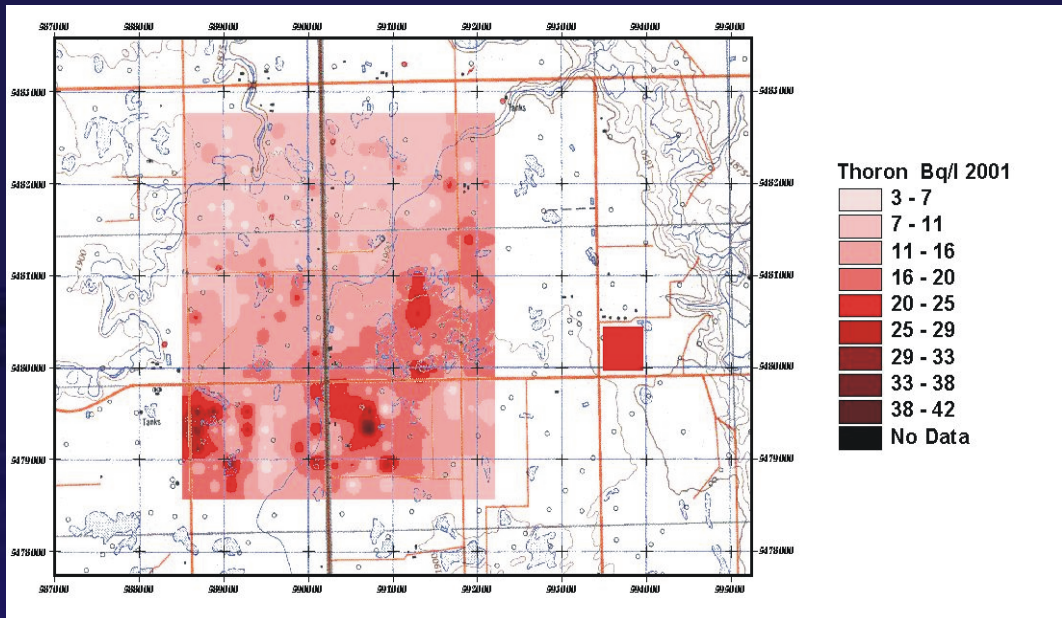
Control Site



Comparison of Thoron
(Bq/l) between
2001 and 2002



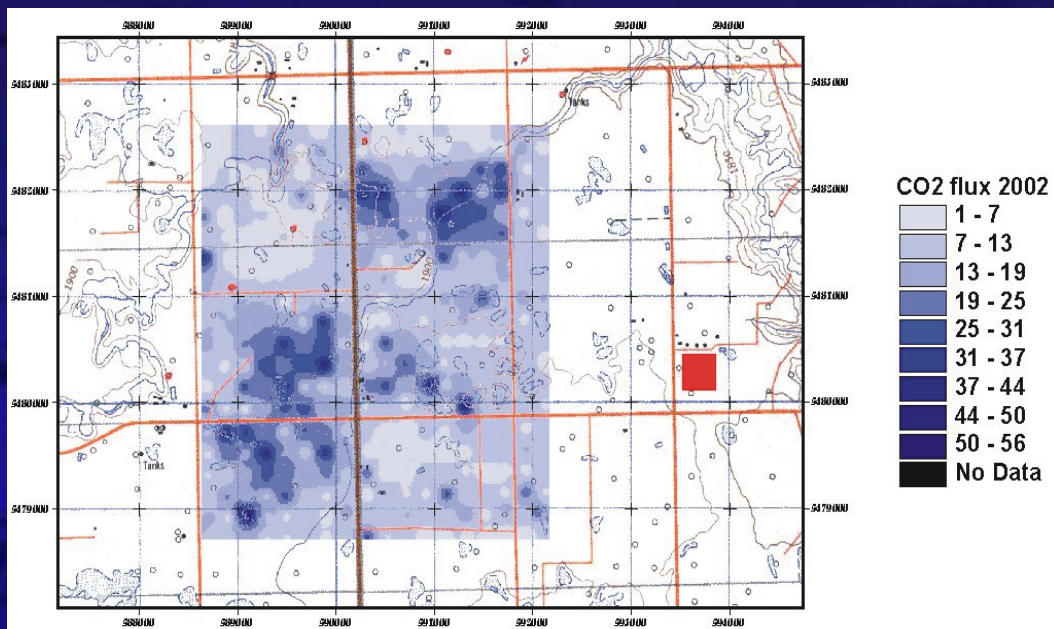
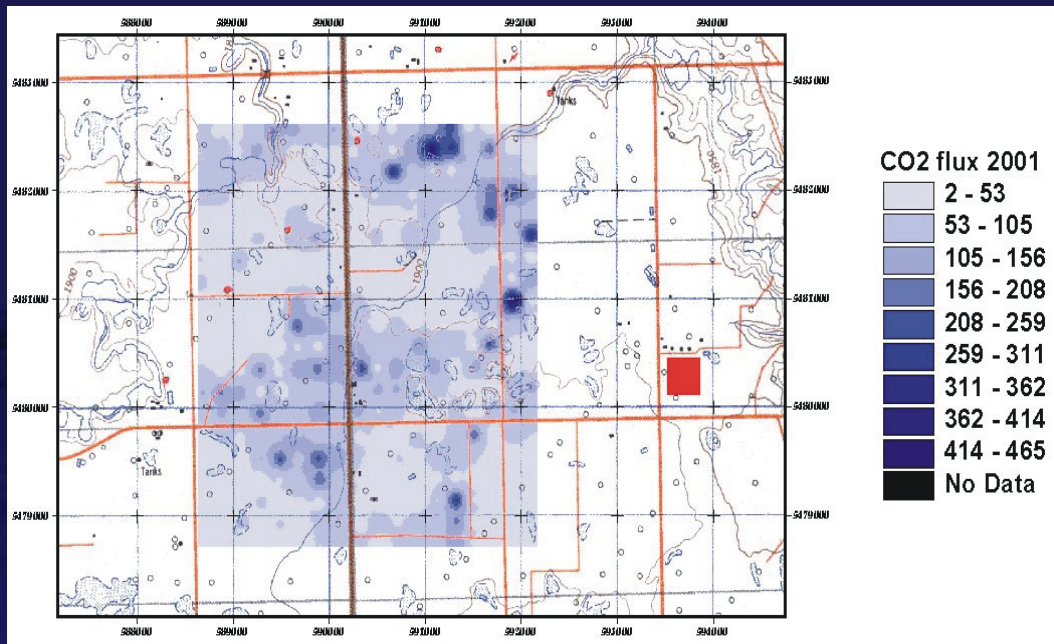
Control Site



Comparison of Thoron
(low skew for 2002)
(Bq/l) between
2001 and 2002



Control Site



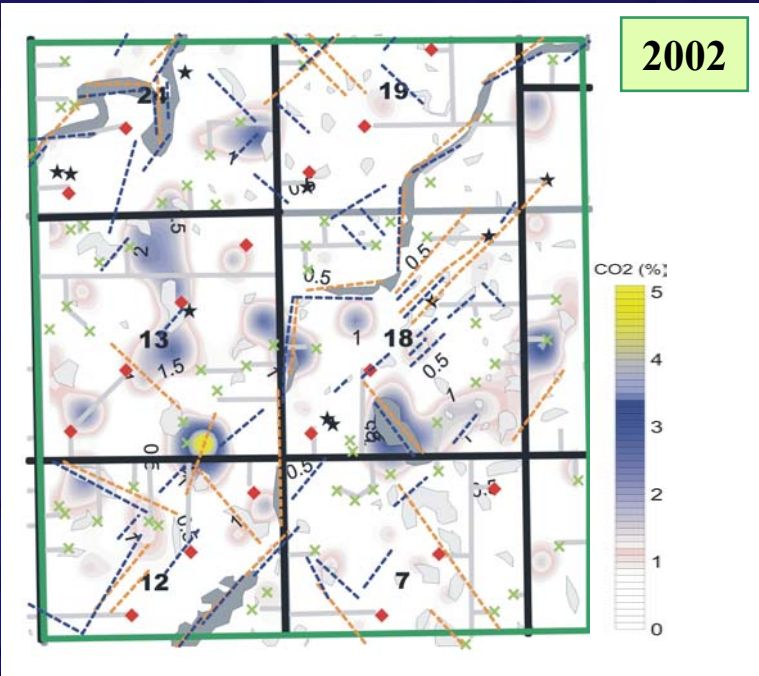
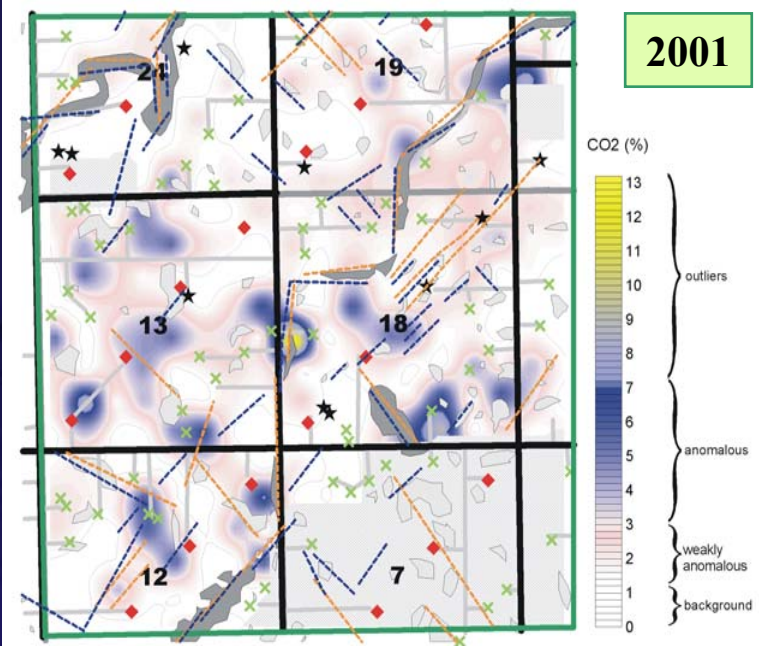
Comparison of CO2 Flux ($\text{gm}^{-2} \text{d}^{-1}$) 2001 and 2002



Control Site

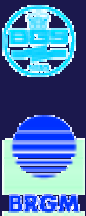


Comparison of Field CO₂ (%) between 2001 and 2002

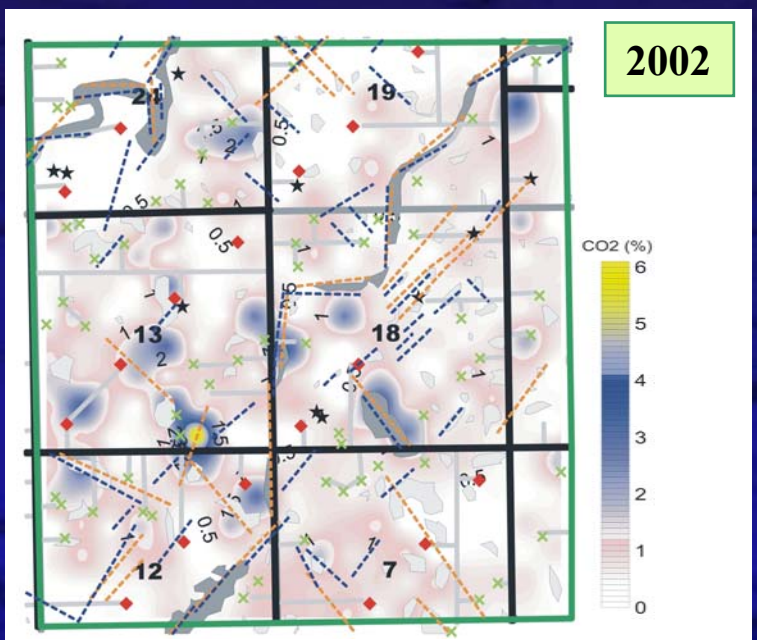
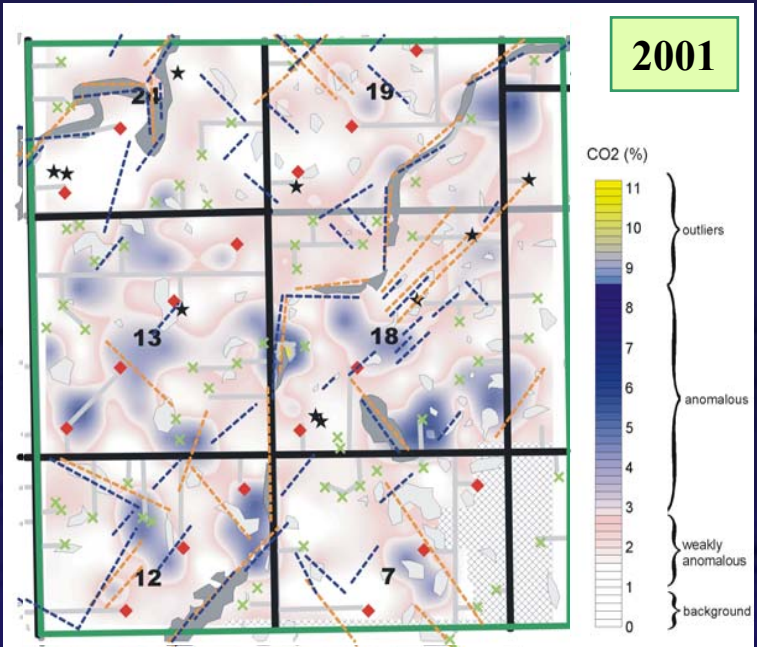


LEGEND

- 1-15000 lineaments
- 1-60000 lineaments
- main roads
- minor roads
- water injection wells
- CO₂ injection wells
- oil extraction wells
- permanent water
- seasonal water



Comparison of URS Laboratory CO₂ (%) between 2001 and 2002

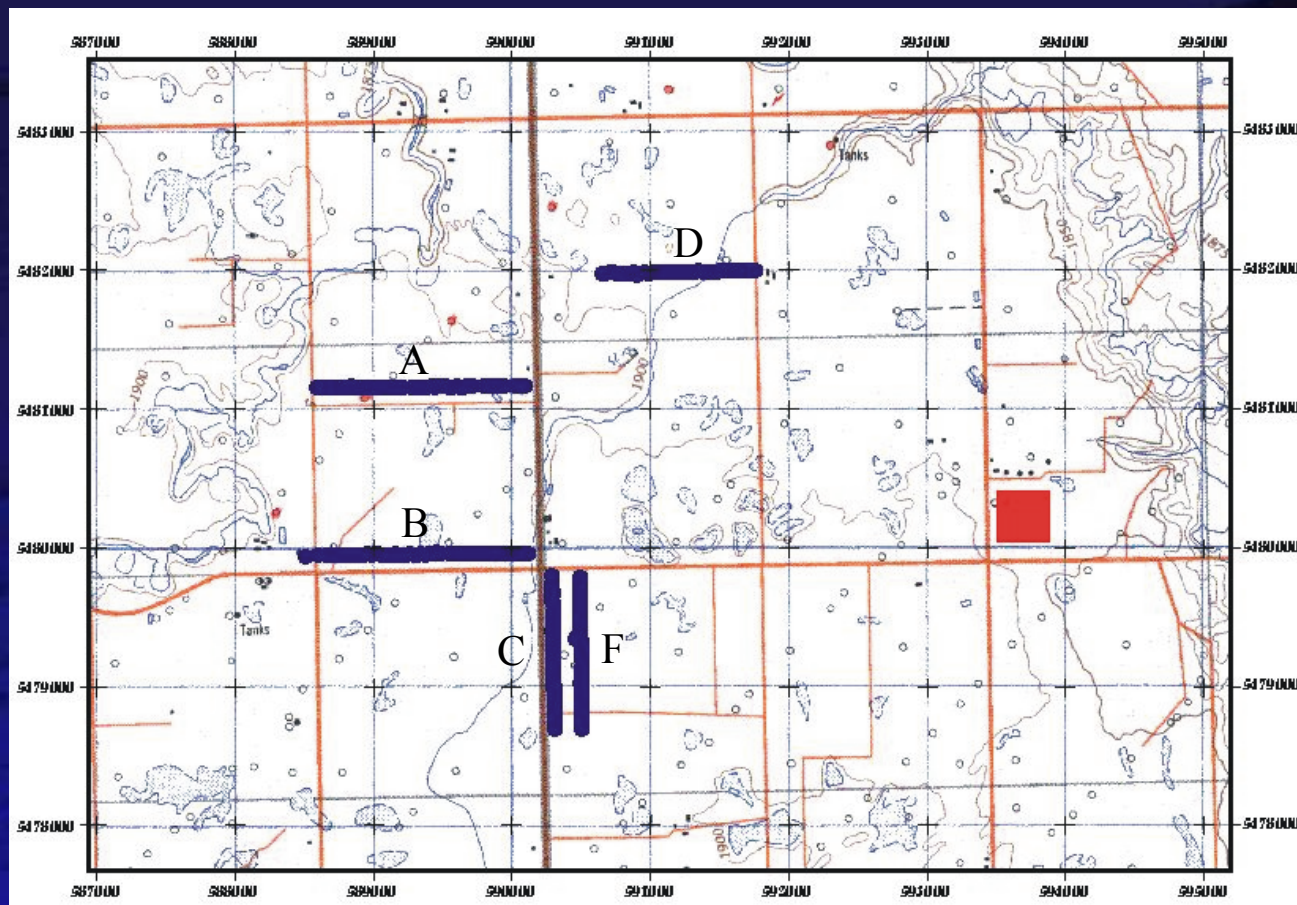


- LEGEND**
- 1-15000 lineaments
 - 1-60000 lineaments
 - main roads
 - minor roads
 - water injection wells
 - CO2 injection wells
 - oil extraction wells
 - permanent water
 - seasonal water

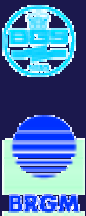




Soil Gas Profile Locations



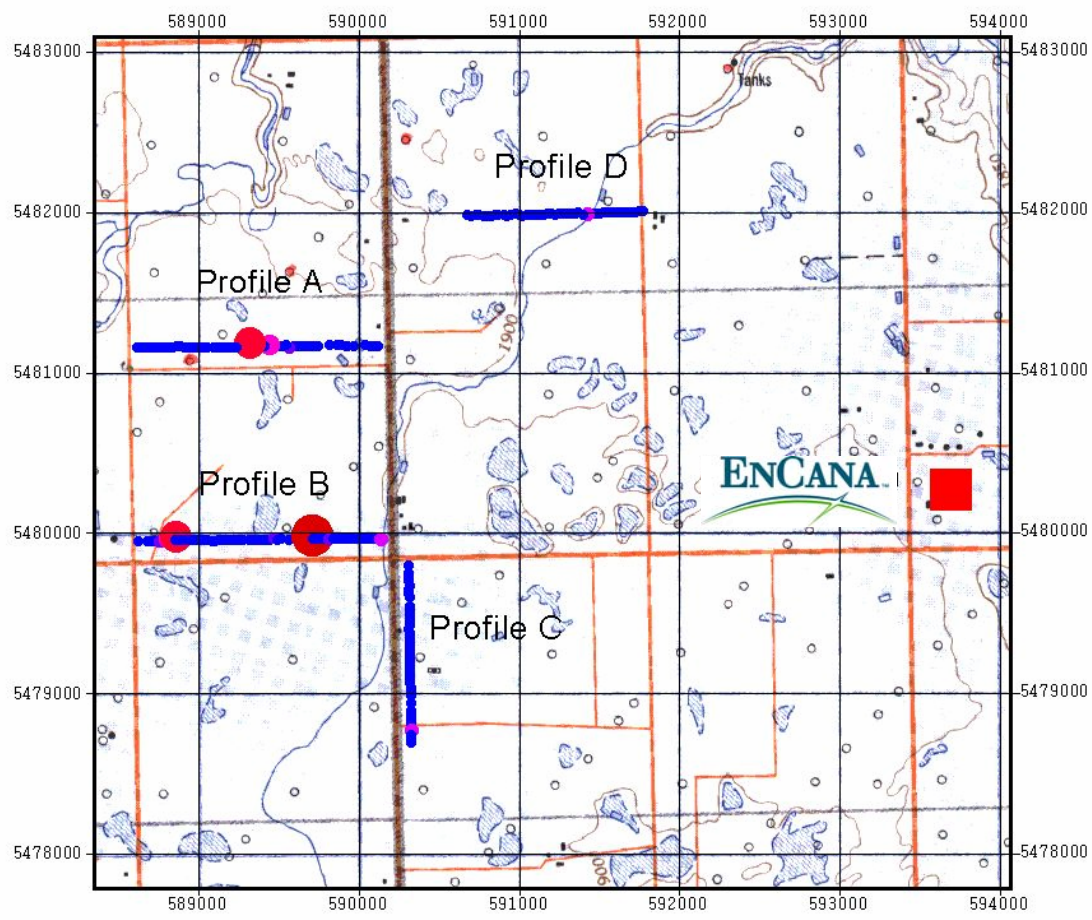
Control Site



Soil Gas Profiles – CO₂

CO₂ %

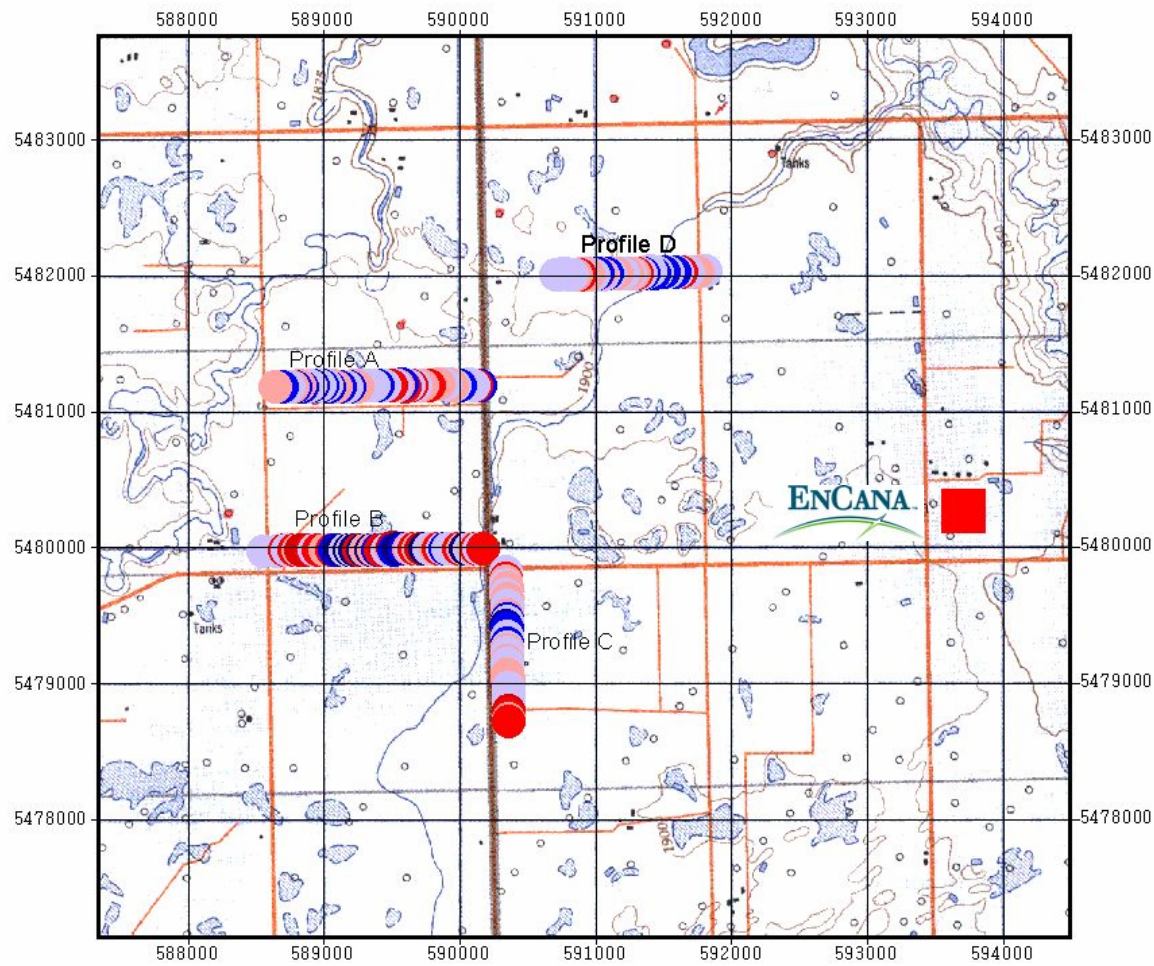
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6

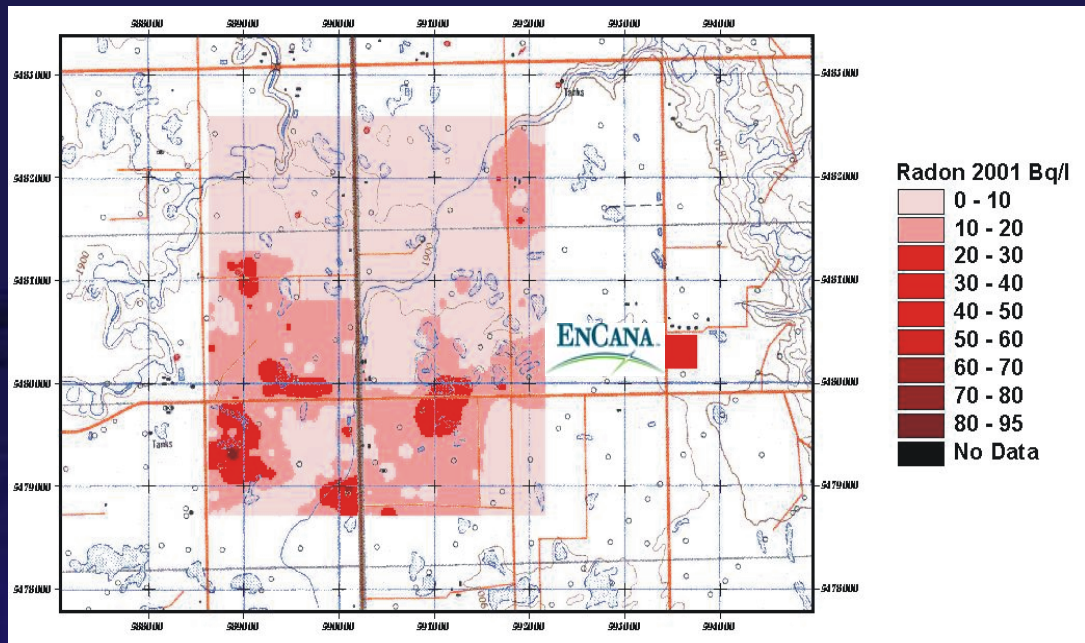


Soil Gas Profiles - Radon

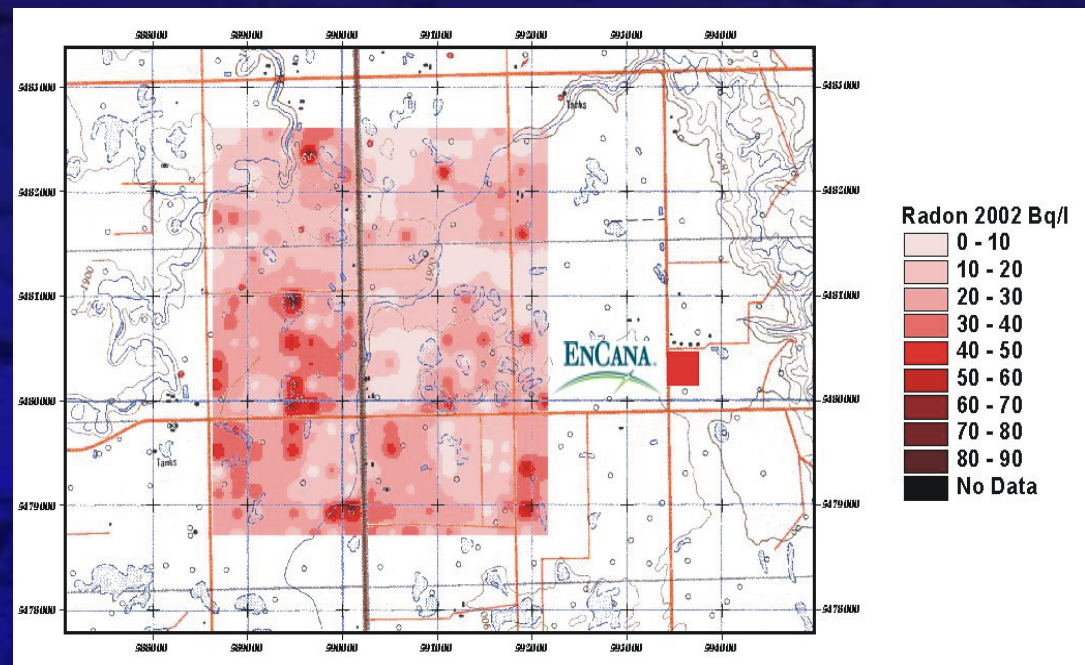
Rn (Bq/l)

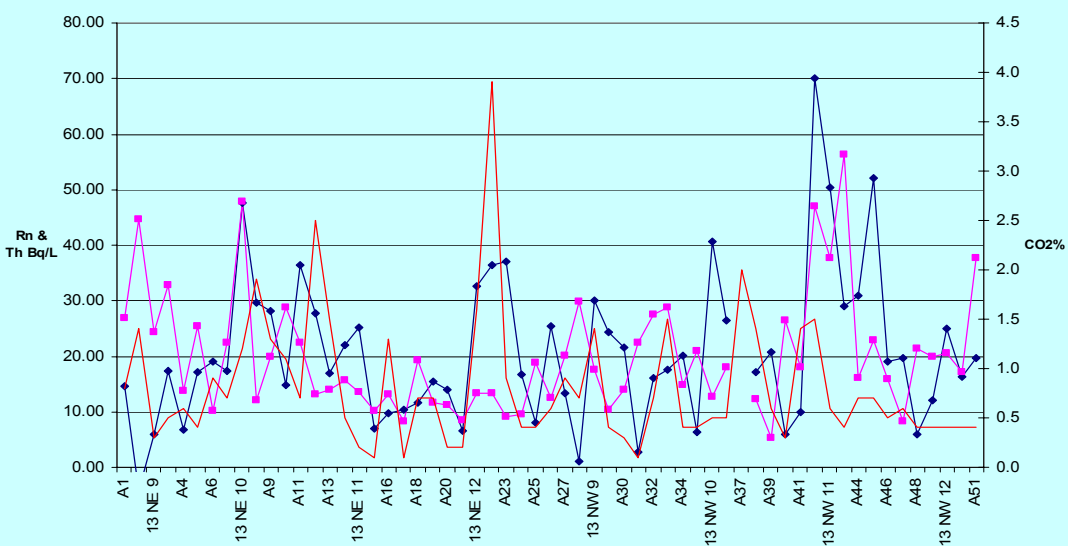
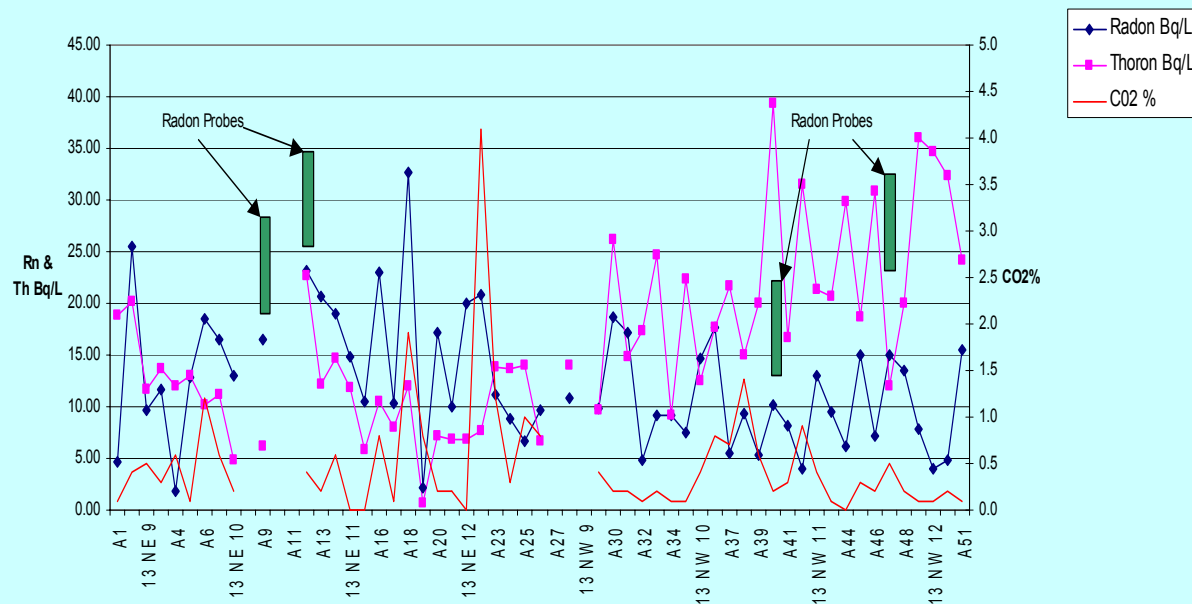
- -14 - 0
- 0 - 7
- 7 - 13
- 13 - 19
- 19 - 33
- 33 - 69



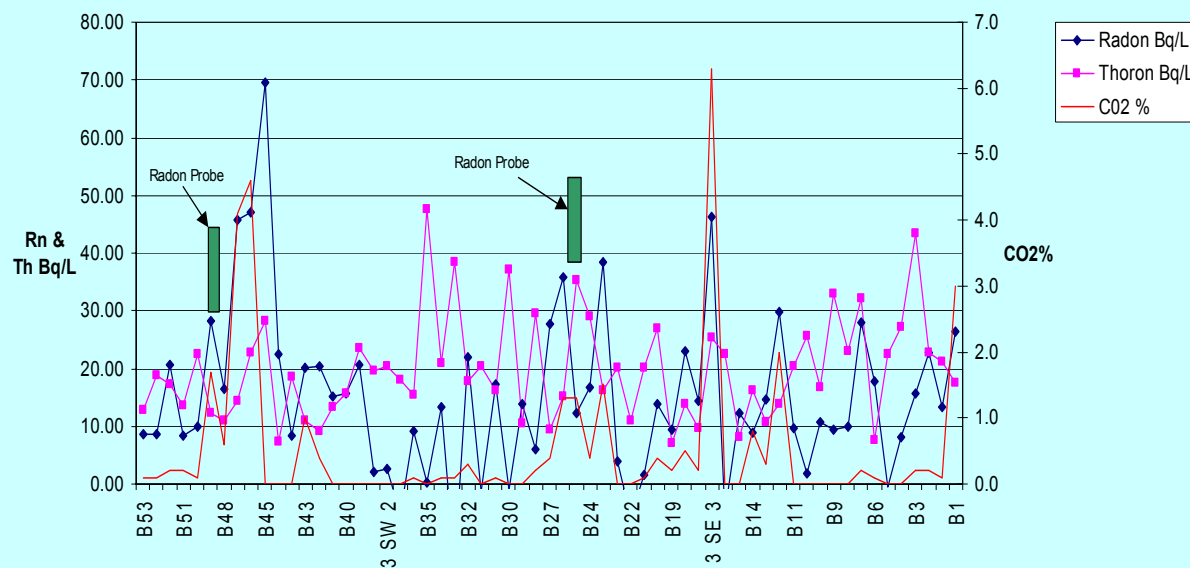


Comparison of Radon (Bq/l) between 2001 and 2002

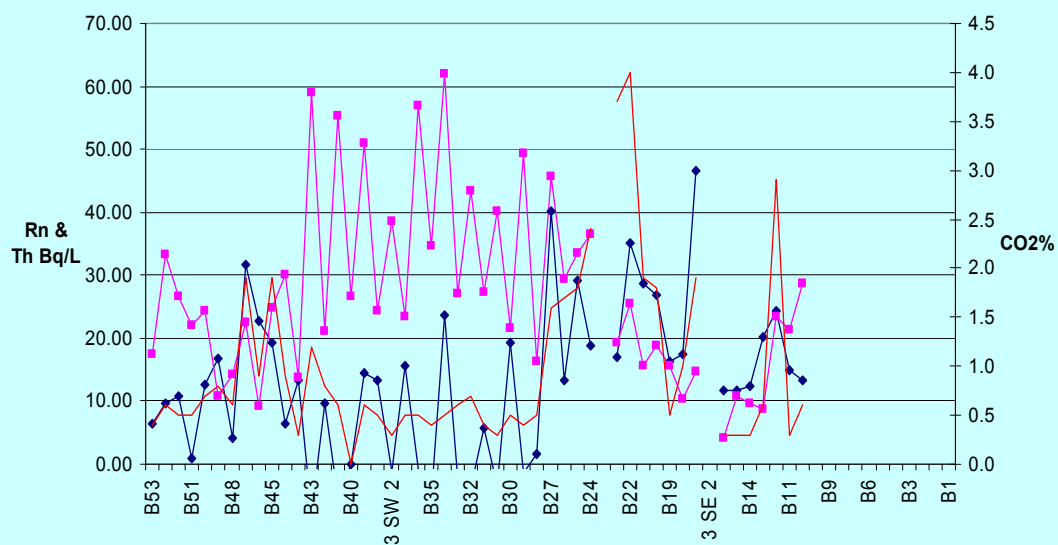




Profile A



Profile B

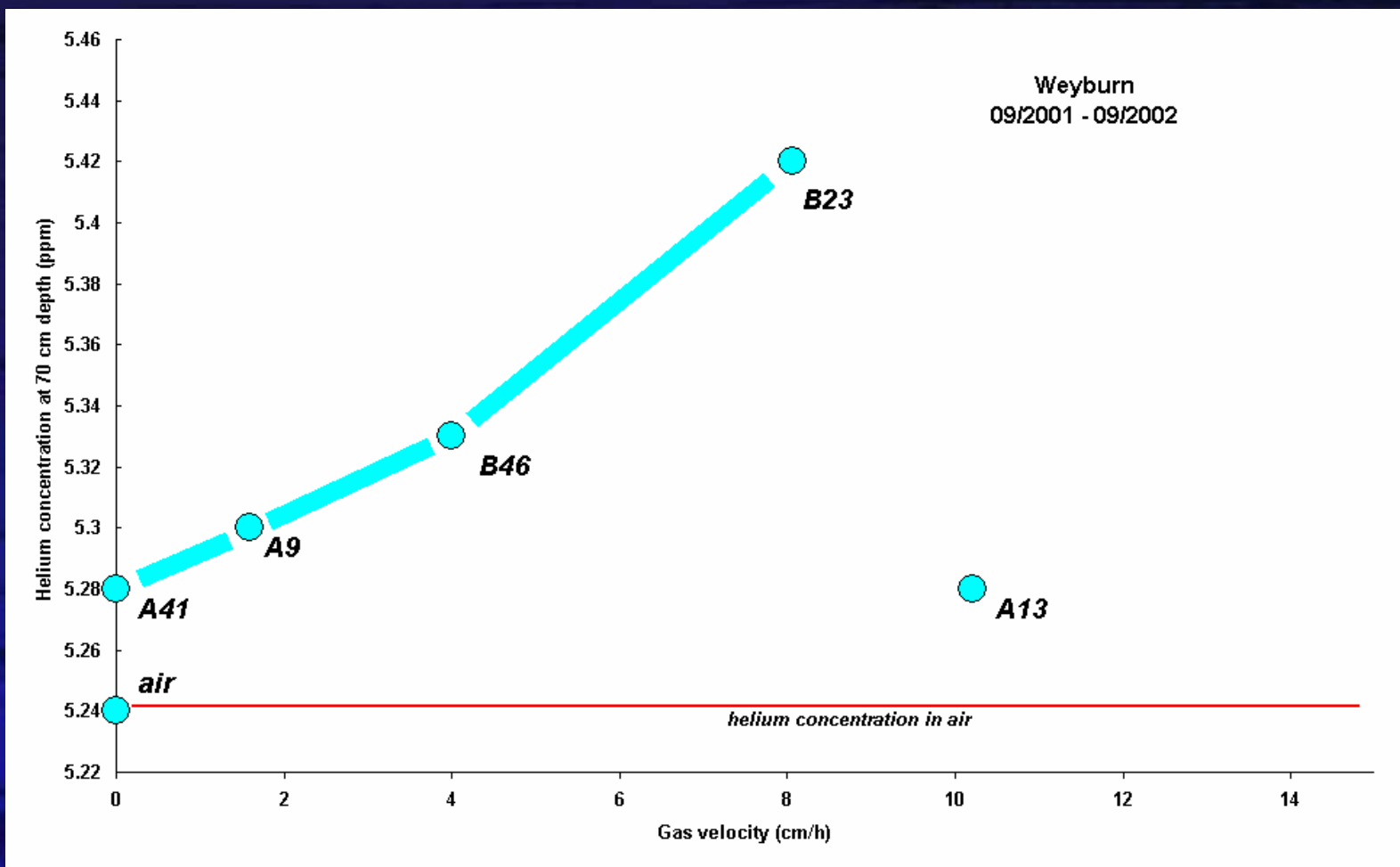






Result of Rn monitoring :

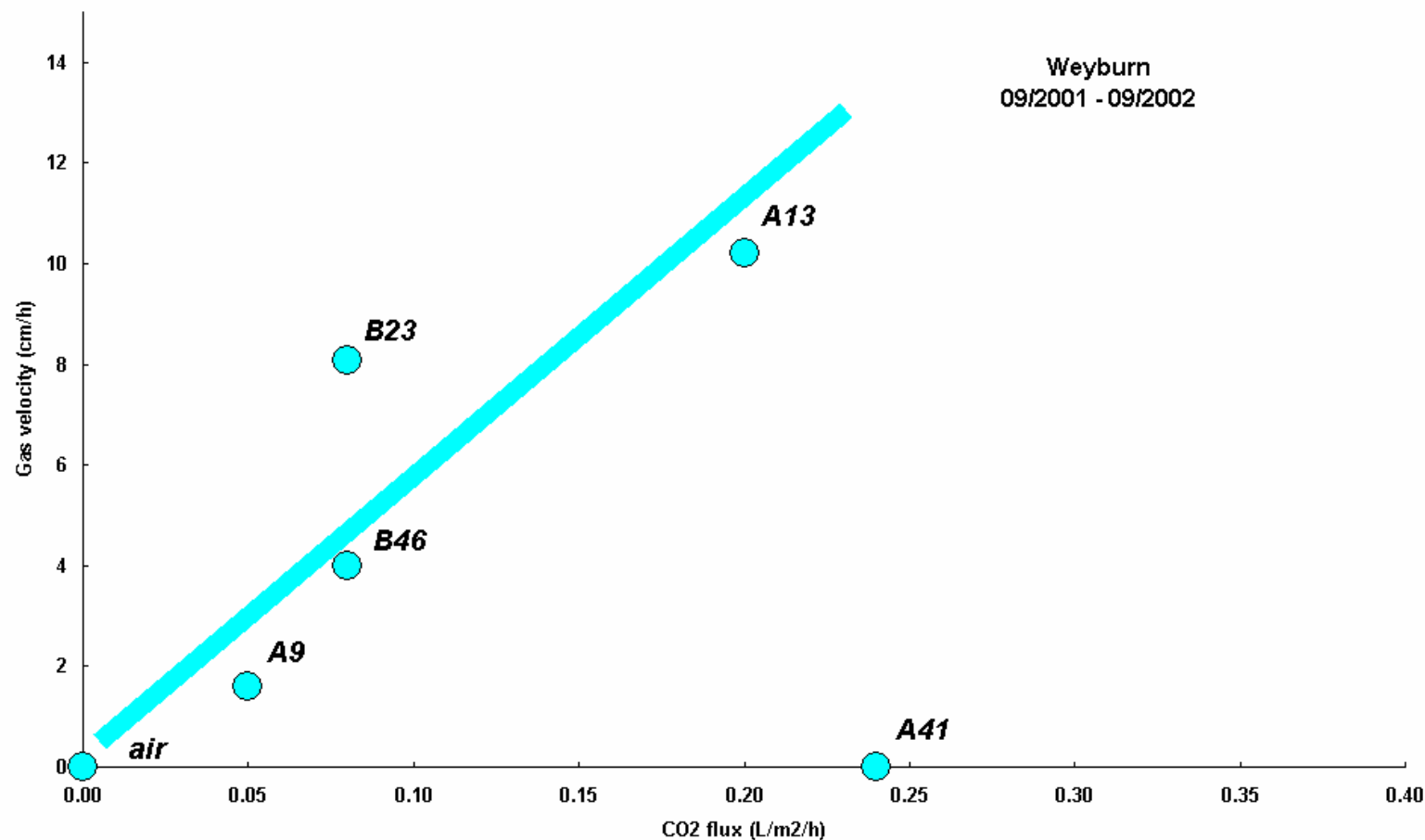
Gas velocity (cm/h), soil He concentration (ppm)





Result of Rn monitoring :

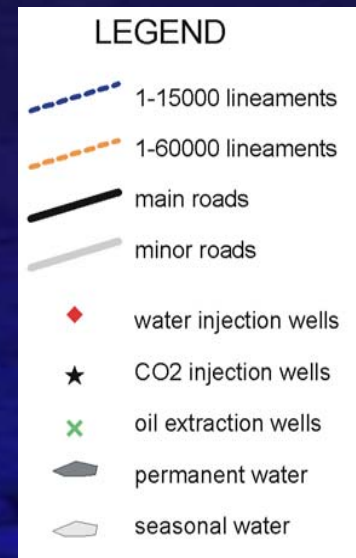
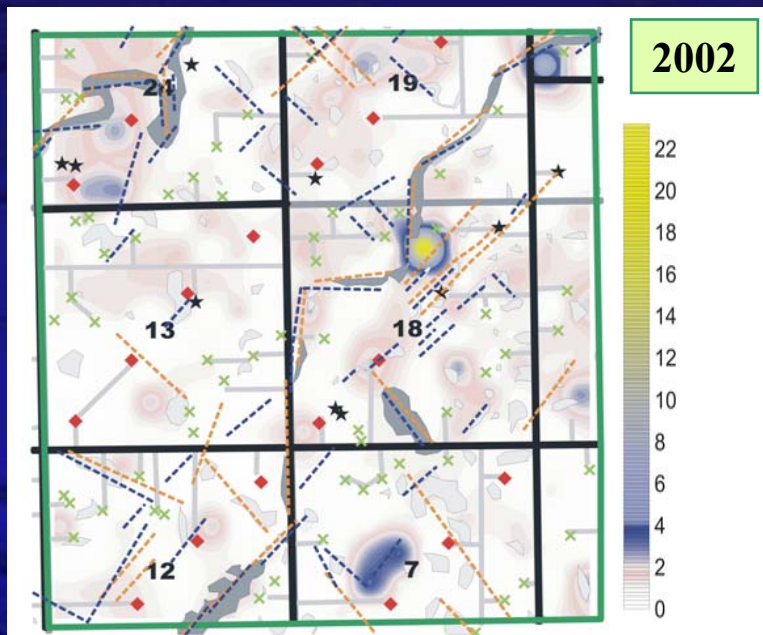
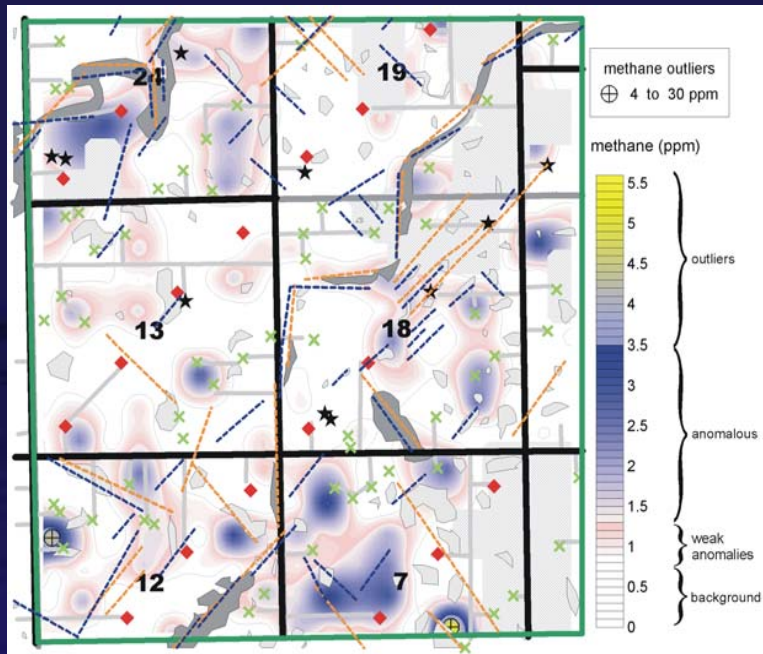
Gas velocity (cm/h), soil CO₂ flux (L/m²/h)

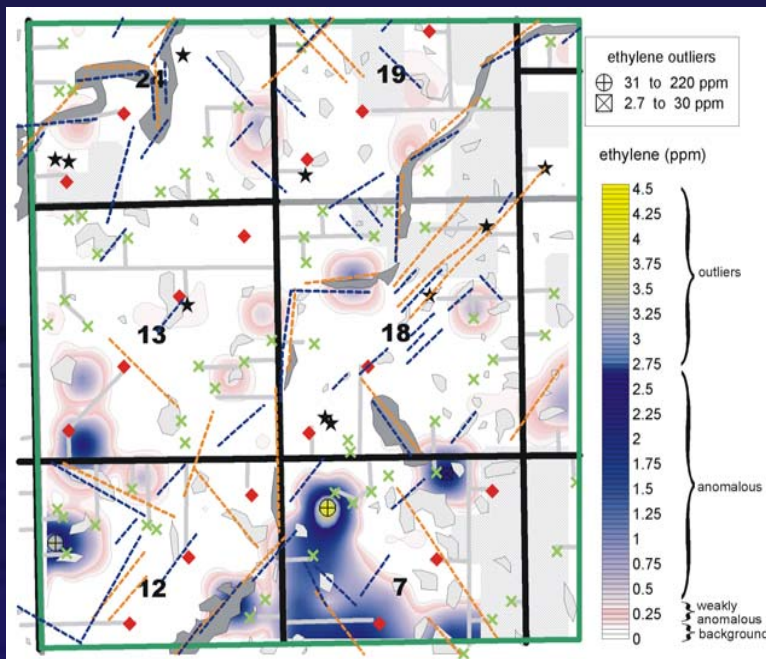
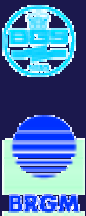




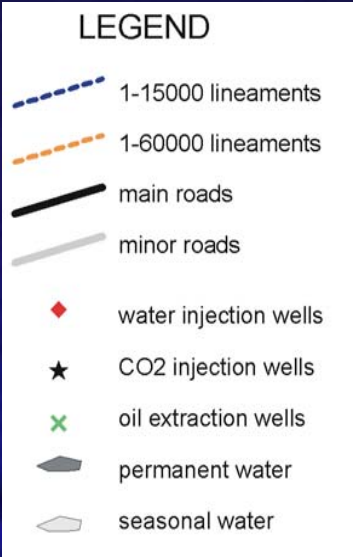
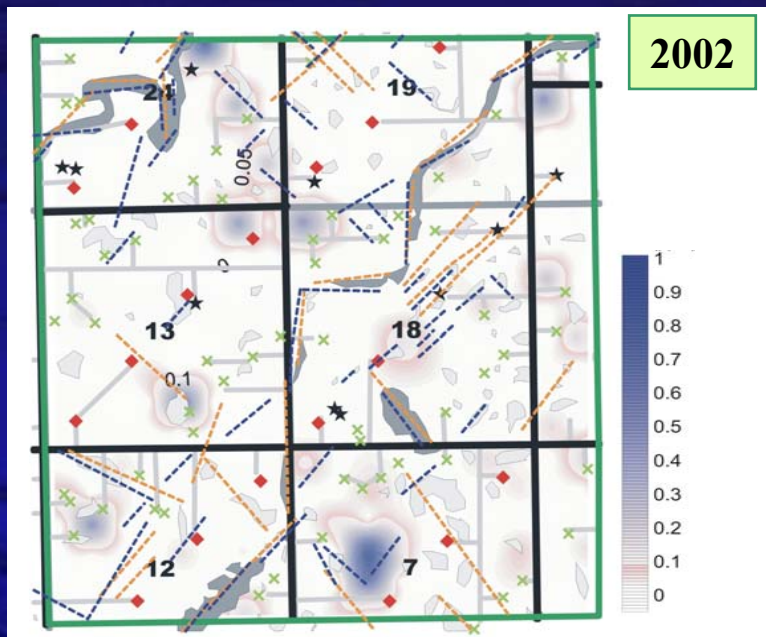


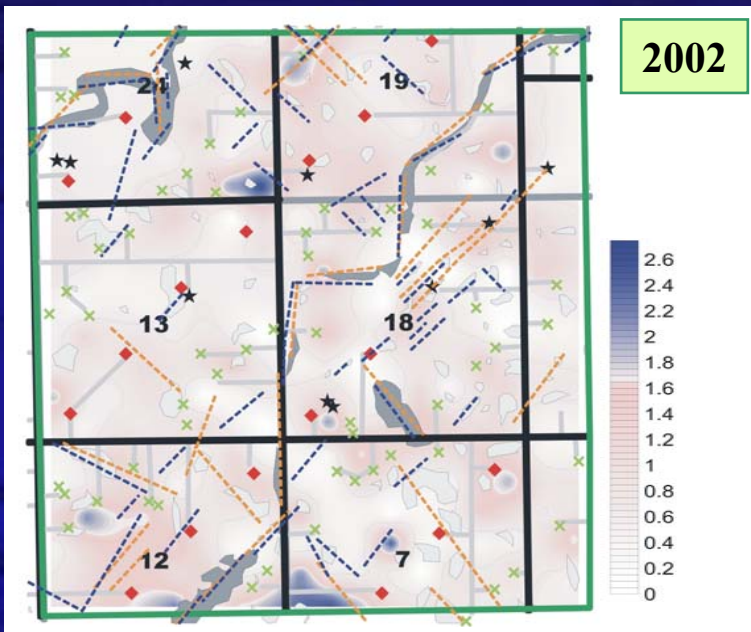
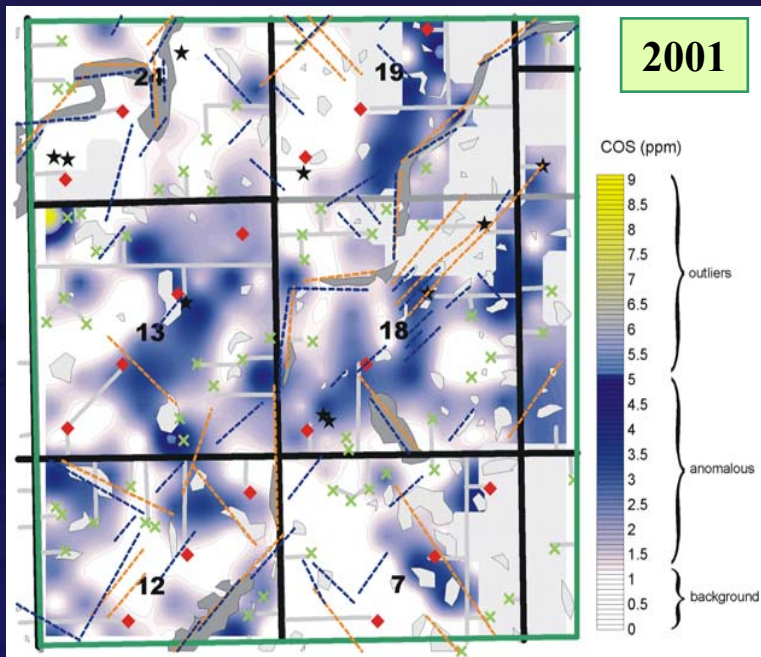
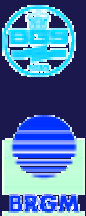
Comparison of Methane (ppm) 2001 and 2002





Comparison of Field Ethylene (ppm) between 2001 and 2002





Comparison of Field COS (ppm) between 2001 and 2002

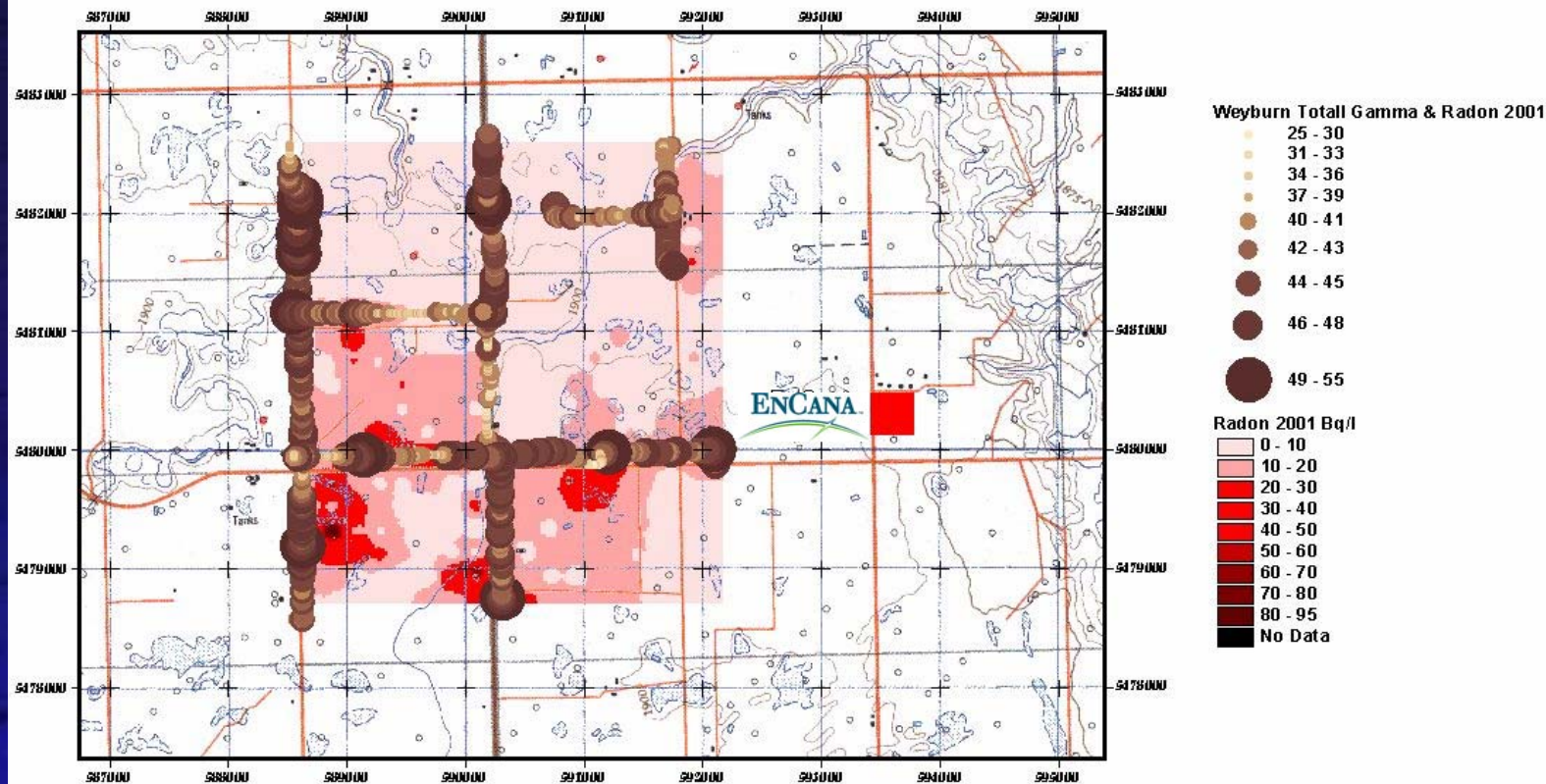
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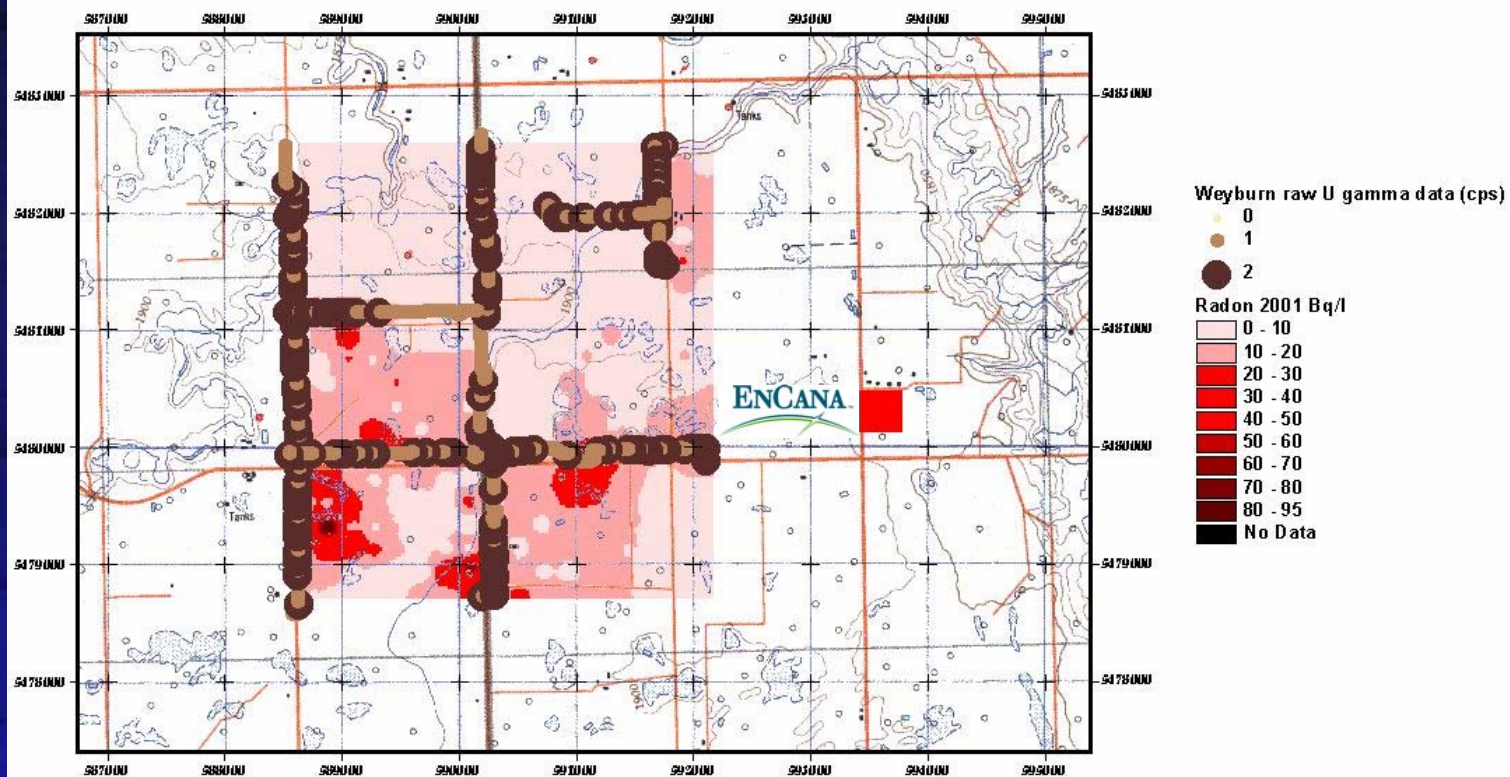


Total gamma & Radon 2001



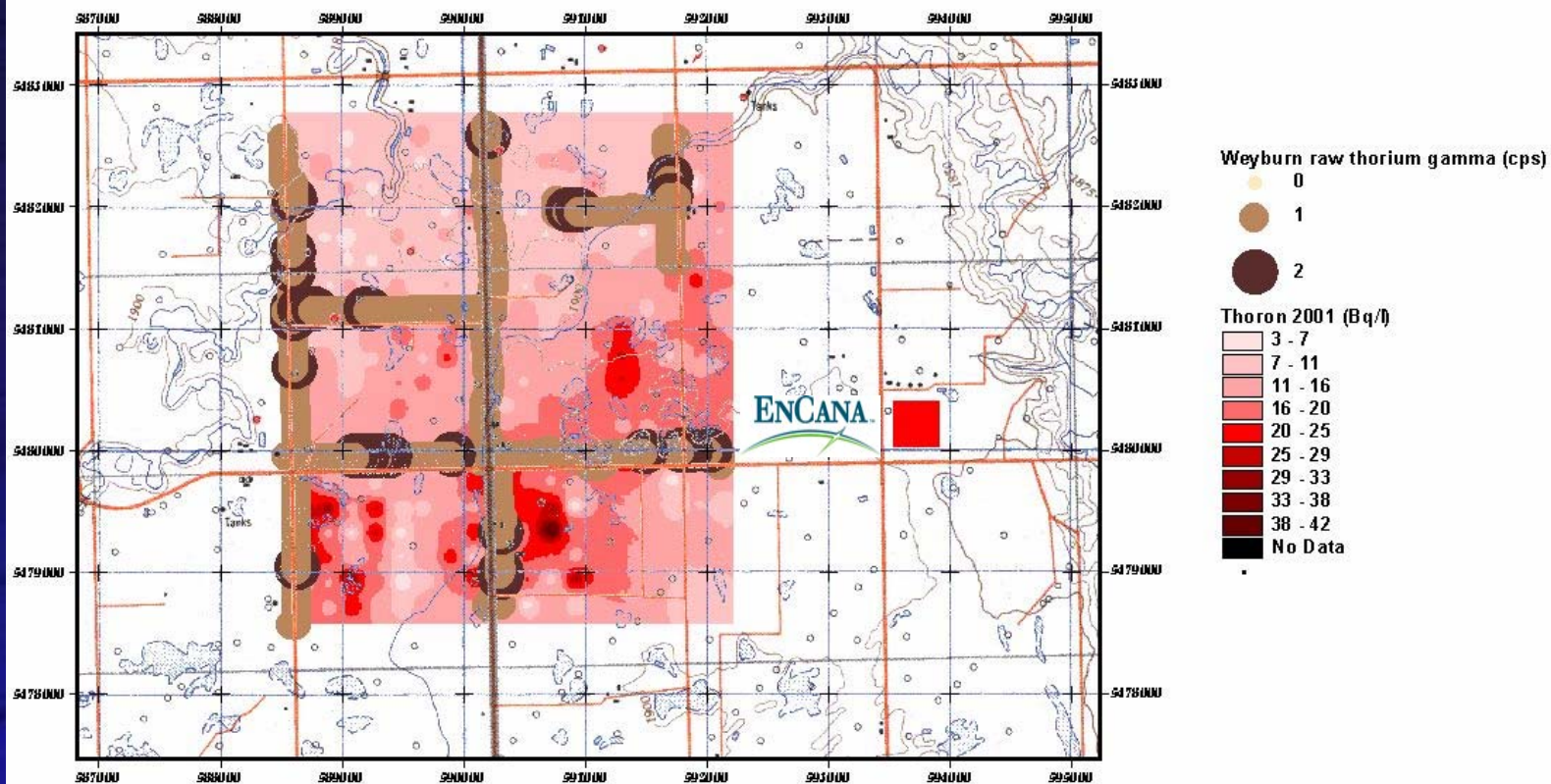


Uranium & Radon 2001





Thorium & Thoron 2001





Conclusions 1

- 2001 baseline complete providing reference data for future comparison.
- 2002 data indicates no significant changes in CO₂ and radon soil gas levels suggesting superficial sources. (Till & vegetation.)
- Long term radon measurements, CO₂ flux and helium provide calculation of upward gas velocity and validate the model from the point of view of gas origins and processes.
Gas velocities 2-10 cm h⁻¹ (~200-900m y⁻¹).
- Possible relationship between structural trends and soil gas anomalies.
- Seasonal variation has strong effect on soil gases. Important to sample at similar times of year to minimise the effects.



Conclusions 2

- Hydrocarbon distribution similar for 2001 and 2002.
- Sulphur species levels highly variable for 2001 and 2002, probably due to seasonal variation effects on shallow biogenics.
- CO₂, N₂ and O₂ data also suggest shallow biogenic origin.
- Gamma data needs more detail.



2003 Developments

- Continued fieldwork vital to assess any changes in soil gas values as flood continues. Repeat grid and profiles for soil gases and flux along with long term radon measurements. Repeat of GC analysis.
- 3 year comparison of soil gas data the priority.
- Assessment of effects on seasonal variation: soil moisture, temperature, rainfall.
- Clastic effects on radon and thoron. Till characterisation drilling (May 2003).
- Lineament and structural considerations in the injection panel and over the oilfield in general.
- Background areas necessary as control.
 - Off oilfield
 - On oilfield but away from injection panel



Future

- Beyond 3 year project window?
 - Establish sites with flux
 - Install long term gas measuring units
 - Monitor with constant communications



Acknowledgements

